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A Plan for In-Air Testing of Metal Detectors

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Technical Memorandum
DRES TM 2000-184
December 2000

National Defence Défense nationale

Canada

A Plan for In-Air Testing of Metal Detectors

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This report is a part of the Canadian Contribution to the IPPTC (International Pilot Project for Technology Co-operation) project on metal detector evaluation.

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Abstract

Canada participates in the International Pilot Project for Technology Co-operation (IPPTC) in landmine detection under the auspices of the Canadian Centre for Mine Action Technologies (CCMAT). The goal of this multinational project is to conduct various laboratory and field tests on a number of commercial metal detectors in their use as landmine detectors. Results of these tests will provide relevant information to potential sponsors and end users of such technology to help them make informed equipment choices in humanitarian demining. This report describes the concepts behind and the detailed implementation of the laboratory tests, designed and led by Canada, and to be conducted at the Defence Research Establishment Suffield.

Résumé

Le Canada participe au projet pilote international pour la coopération technologique (IPPTC), dans le domaine de la détection de mines terrestres, avec l'appui du Centre canadien des technologies de dminage (CCTD). L'objectif de ce projet multinational est de soumettre à différents essais, en laboratoire et sur le terrain, un certain nombre de détecteurs de métaux commerciaux utilisés comme détecteurs de mines terrestres. Les résultats de ces essais fourniront des renseignements utiles aux éventuels commanditaires et utilisateurs finaux d'une telle technologie et les aideront à faire des choix éclairés en matière de matériel de déminage humanitaire. Le présent rapport décrit différents éléments des essais en laboratoire, conçus et organisés par le Canada, qui seront effectués au Centre de recherches pour la défense Suffield. On y trouve les concepts de base des essais et des détails sur leur mise en œuvre.

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Executive summary

Canada is participating in the International Pilot Project for Technology Co-operation (IPPTC) in landmine detection under the auspices of the Canadian Centre for Mine Action Technologies (CCMAT). Other participants are government agencies and research institutes from the U.S.A., the U.K., the Netherlands and the European Union. Under this project a series of laboratory and field tests will be conducted on a number of commercial metal/mine detector models in order to provide relevant information to potential sponsors and end users of such technology to help them make informed decisions about their equipment selection in humanitarian demining.

This document describes the In-Air Tests which are a part of the Canadian contribution to the IPPTC. The main purpose of these tests, to be conducted at the Defence Research Establishment Suffield (DRES), is to understand certain basic operational parameters of the detectors in a controlled laboratory environment. A total of six tests will be performed. Four of these, namely, Calibration, Drift, Moisture and Sweep-Speed Tests will measure the effect on a detector's performance of initial set-up procedure, electronic drift, water gathering on the detector head and the speed with which a detector is swept. In addition, The Sensitivity Test will measure the ability of a detector to detect a variety of landmines and other targets. Also, The Scan Profile Test will determine detector "footprints", which indicate how the detectability of a target may depend on its horizontal and vertical location with respect to the search coil. Future evaluations of this nature should consider conducting additional tests to determine the effect of battery state, temperature and humidity, ambient electromagnetic noise, and operator on detector performance.

This document includes very detailed technical instructions written as "checklists" for personnel who will conduct the In-Air Tests using a purpose-built mechanical apparatus and electronic data collection system.

Y. Das, J.D. Toews . 2001. A Plan for In-Air Testing of Metal Detectors.
DRES TM 2000-184. Defence Research Establishment Suffield.

Sommaire

Le Canada participe présentement au projet pilote international pour la coopération technologique (IPPTC), dans le domaine de la détection de mines terrestres, avec l'appui du Centre canadien des technologies de déminage (CCTD). Les autres participants comprennent des organismes gouvernementaux et des instituts de recherche des États-Unis, du Royaume-Uni, des Pays-Bas et de l'Union européenne. Dans le cadre de ce projet, un certain nombre de détecteurs de métaux ou détecteurs de mines commerciaux seront soumis à une série d'essais, en laboratoire et sur le terrain, pour fournir des renseignements utiles aux éventuels commanditaires et utilisateurs finaux d'une telle technologie et les aider à faire des choix éclairés en matière de matériel de déminage humanitaire.

Le présent document décrit les essais effectués dans l'air ambiant qui constituent un élément de la contribution canadienne au IPPTC. Le principal objectif de ces essais, qui seront effectués au Centre de recherches pour la défense Suffield (CRDS), est de comprendre certains paramètres de fonctionnement de base des détecteurs, dans une atmosphère contrôlée de laboratoire. Six essais distincts seront réalisés. Quatre de ces essais, à savoir ceux d'Étalonnage, de Dérive, de Teneur en eau et de Vitesse de balayage, permettront de déterminer les effets qu'ont la méthode initiale de réglage et d'étalonnage, la dérive électronique, la condensation de l'eau sur la tête de détection et la vitesse de balayage, sur la performance du détecteur. De plus, l'essai de Sensibilité permettra de mesurer l'aptitude d'un détecteur à détecter différentes mines terrestres et d'autres cibles. En outre, l'essai de Profil de balayage déterminera les ≪ empreintes ≫ du détecteur, lesquelles indiquent la manière dont la détectabilité d'une cible dépend des composantes horizontale et verticale de sa position, relativement à la bobine détectrice. Les futures études de ce type devraient envisager la réalisation d'essais additionnels pour déterminer les effets de l'état de charge de la pile, de la température et de l'humidité, du bruit électromagnétique ambiant et de l'expérience personnelle de l'opérateur sur la performance du détecteur.

Le présent document comprend des instructions techniques très détaillées, présentées sous forme de ≪ listes de vérification ≫, pour le personnel qui effectuera les essais dans l'air ambiant à l'aide d'un appareil construit dans ce but et d'un système de collecte de données électroniques.

Y. Das, J.D. Toews . 2001. Le plan d'une expérience sur les detecteurs du métal. DRES TM 2000-184. Centre de recherches pour la défense, Suffield.

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Acknowledgements

The authors would like to thank Mr. Kevin Russell for writing the LabVIEW® data acquisition software used in this project.

1. Introduction

This document describes tests to be conducted at the Defence Research Establishment Suffield (DRES) as a part of Canadian contribution to the International Pilot Project for Technology Co-operation (IPPTC) in landmine detection [1]. The participants of this project are government agencies and research institutes from Canada, the European Union, the Netherlands, the U.K. and the U.S.A. Canadian participation in the IPPTC is under the auspices of the Canadian Centre for Mine Action Technologies (CCMAT) which is co-located with DRES. The goal of the IPPTC is to conduct various laboratory and field tests on a number of commercial metal detectors in their use as landmine detectors. Results of these tests will provide relevant information to potential sponsors and end users of such technology to help them make informed equipment choices in humanitarian demining.

The work is being carried out in a number of phases. Phase 1 and Phase 2 consisted of purchasing the detectors and the IPPTC technical evaluation team familiarizing themselves with the operation of the detectors. Three samples each of a total of 29 models of handheld commercial-off-the-shelf (COTS) metal detectors were purchased from a number of manufacturers who had claimed their products to be suitable for landmine detection. All the detectors were also subjected to a simple entrance test to qualify for further testing under this project. The aim of Phase 3 was to assess the performance of the detectors in finding targets buried in known soil types, and to this end tests were conducted at the HOM-2000 soil test lanes at the Physics and Electronics Laboratory of Netherlands Organization for Applied Scientific Research (TNO-FEL) in The Hague [2]. Phase 4 consists of controlled laboratory tests (referred to as the In-Air Tests) to be led by Canada and an ergonomic assessment of the detectors to be led by the U.K. Phase 5, to be led by the U.S.A., consists of testing the detectors under field conditions in a number of countries with well-known landmine problems. Phase 6 includes data analysis, preparation of reports and dissemination of gathered information. The different phases are seen as complementing each other, and technical representatives of all participants of IPPTC are expected to take part in all phases of the project.

The main purpose of this document to describe the In-Air Tests and to serve as a how-to manual for conducting them using the experimental facility at DRES.

2. Concept of Tests

The concept behind the tests to be described came from experience in testing a large number of detectors from various manufacturers worldwide. Ideas behind these tests and other issues in evaluating performance of metal detectors are summarized in [3], a copy of which is included as Annex A. Tests to be conducted under Phase 4 of the IPPTC project are only a subset of laboratory tests that could and should be conducted if there were no time or resource constraints. The tests which will be conducted in a

controlled laboratory environment will focus on a detector's ability to detect objects in air (also referred to as its in-air sensitivity) and will assess how this sensitivity is affected by various parameters that model some real-world conditions. While a detector's ability to detect objects in air does not indicate its ability to detect objects buried in the ground, such controlled tests are very useful in comparing certain basic performance factors and in understanding a detector's performance in the field. The following tests, which are described in detail later in the document, will be conducted on two samples of each detector model during the in-air laboratory testing at DRES.

1. **Calibration:** This test will determine the repeatability of the initial set-up or "calibration" procedure of a detector.

2. **Drift:** This test will determine how much the sensitivity of a detector changes over a half-hour period following an initial warm-up.

3. **Sweep Speed:** This test will determine how much the sensitivity of a detector changes as a function of the speed with which the detector head is swept over a target.

4. **Moisture:** This test will determine how much the sensitivity changes when moisture is applied to the sensor head.

5. **Sensitivity:** This test will determine a detector's ability to detect a variety of targets.

6. **Scan Profile:** This test will determine the scan profile or "footprint" of a detector, that is, the variation of sensitivity as a function of a target's location on a plane parallel to the detector head.

In addition to the above quantitative tests, we will actively look for any unusual or unique behaviour of a detector that may be of interest to the user.

If more time and resources were available, we would have conducted three additional tests. These are: (a) **power consumption** and **effect of battery state**; (b) **effect of temperature and humidity**; and (c) **effect of ambient electromagnetic noise**.

Most detectors have a low battery indicator which is meant to assure a given performance as long as the battery voltage is over a certain value. As well, some preliminary tests with a very commonly used detector indicated that the battery state issue is not critical enough to warrant testing at this time at the detriment of other tests. However, the effects (b) and (c) are deemed to be important in humanitarian demining and the fact that they are not assessed must be viewed as one of **the deficiencies of the current project.**

The in-air laboratory tests should have been logically done before the tests at the soil lanes, but the order of testing was reversed so that the outdoor (soil lanes) testing could be completed during the summer months in The Netherlands.

3. Experimental Facility

3.1 The Laboratory

All in-air testing at DRES will be conducted in the Foam Dome (Fig. 1), an all weather foam building which due to its non-conductive, non-magnetic construction can be used to make very low noise magnetic and low frequency electromagnetic measurements.

3.2 The Automated Scanner

In some of our previous tests [3], targets were moved over sensor heads by hand. This process, although very expedient and almost indispensable in a field situation, might be inconsistent and difficult to control. An apparatus consisting of a scanner and a target holder, both built of non-metallic materials, have been specially developed for the IPPTC project to provide accurate mechanical control over sweep speed and target location. Various views of this setup are shown in Figures 2 to 6. Further details of the device will be the subject of future DRES reports. Briefly speaking, a barrel cam, suitable gears and other mechanisms are used to convert the rotational motion of an electric motor (or other suitable driving mechanism) into a side-to-side linear motion of the detector head which is attached to a mount moving on the barrel cam. The sweep speed of the detector head, which is measured by using an optical encoder mounted on the long shaft driven by the motor, is varied by controlling the speed of the motor. The controller of the motor has speeds indicated only as a percentage (%) and in our set-up 100% nominally corresponds to a head speed of 1 m/s. The relationship between the % indications on the controller and the actual head speed is not strictly linear. A calibration has to be done to relate the % settings on the motor controller to the speed of the detector. In this document, we will use only the % numbers to refer to the speeds. The length of the drive shaft is chosen to ensure that the electric motor, which is selected for its low EMI, is sufficiently distant not to adversely affect the metal detector.

The scanner can be set up to automatically move the detector head over a 1 m × 1 m area (area or 2-D scan mode) in a raster scan fashion or to repeatedly move the head over a chosen line (line or 1-D scan mode). In all our tests except one (The Scan Profile Test), the scanner would be used in the 1-D mode.

Figure 1: *The Non-metallic Building (Foam Dome)*

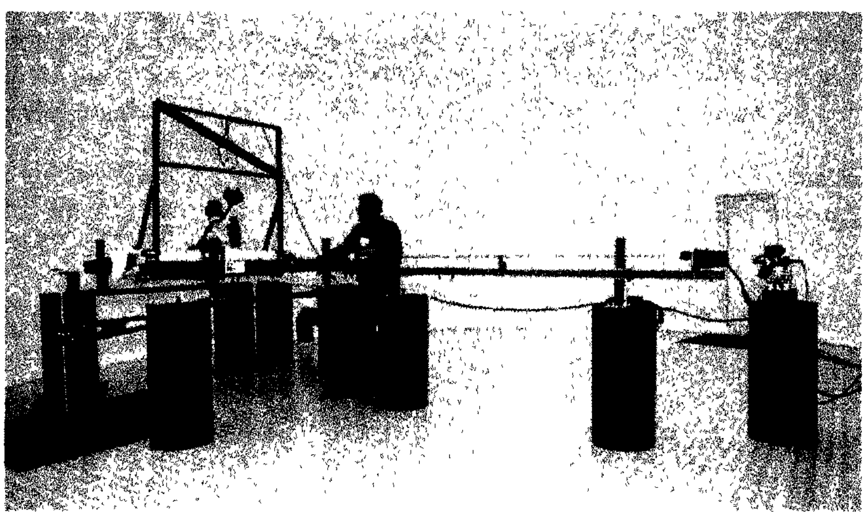

Figure 2: *An Overall View of the Scanning Apparatus*

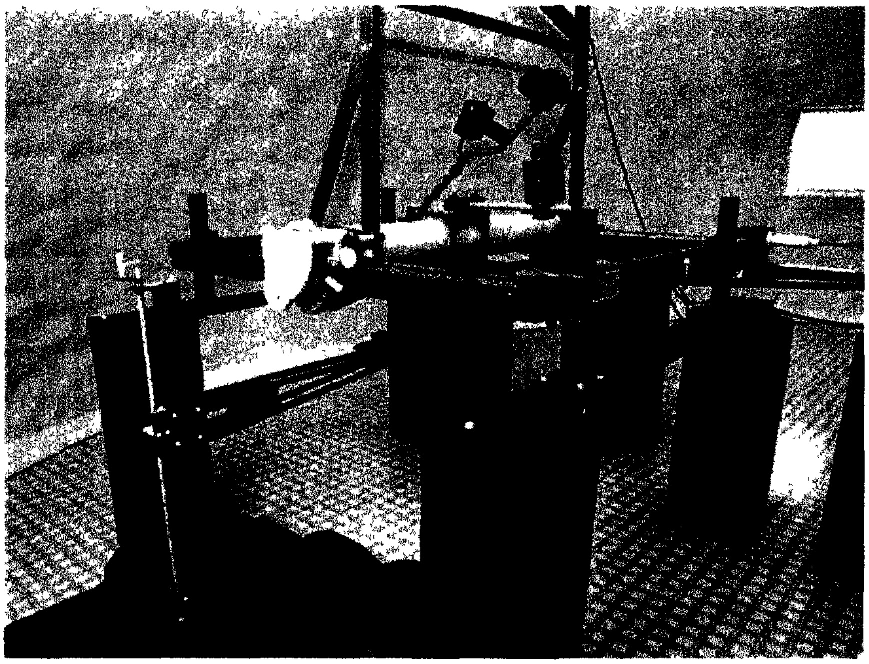

Figure 3: *Close-up Side View of the Scanner and the Target Holder*

Figure 4: *Close-up Top View of the Scanner*

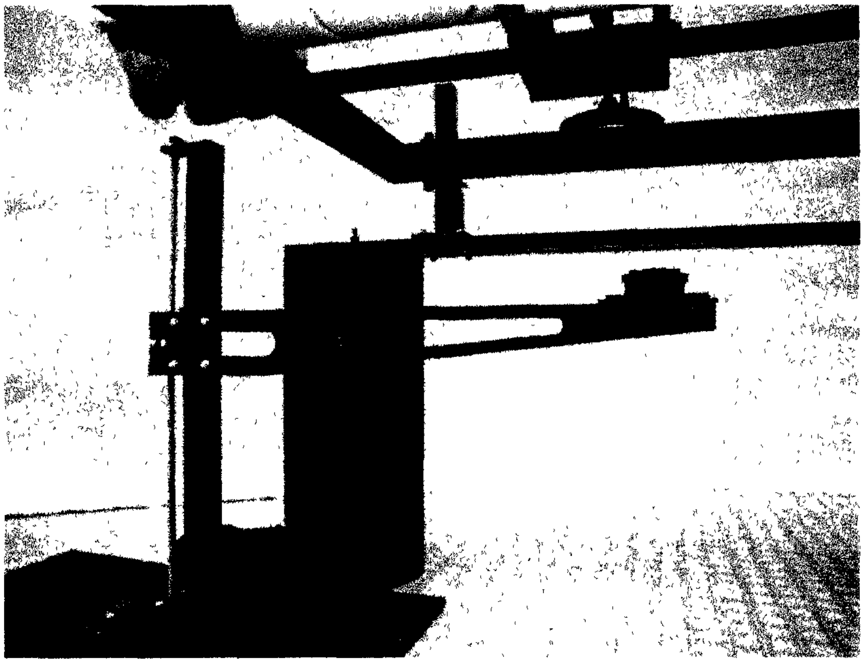

Figure 5: *Close-up View of the Target Holder*

Figure 6: *Close-up View of the Operator Work Station*

3.3 The Data Acquisition System

Essentially all commercial metal detectors produce an audio output through a headphone or a speaker. An operator listens for a change in the audio output of a detector to decide if a target is present. Such a decision depends critically on an individual's hearing, judgement, attentiveness, experience and so on, particularly when the change in audio signal is small, which is the case when one tries to determine the maximum distance at which a target is detectable. Becuase of the potentially significant dependence of the measurements on the subjectivity of the operator, it is prferable to digitally record the audio signals from the detectors. The recorded signal, in addition to serving as a record of the tests, can be subsequently processed by a suitable computer algorithm or be analyzed by any number of human operators in order to arrive at decisions free of operator bias.

The quality of the headphone used in a detector affects its audio signal and hence, in order to preserve the sound of a detector one should ideally record the acoustic output directly from its headphone. We acquired and evaluated a Georg Neumann KU100 dummy head designed for such an application. The dummy head is a replica of the human head with a microphone and preamplifier built into each ear. We found that although this method could in principle be used, we could not isolate, to a satisfactory degree, various extraneous sounds (e.g., scanner noise, vehicles driving by, helicopters near by, and so on) that are inevitably present at our test site. Earlier, the test site at TNO-FEL was also found to be unsuitable for direct acoustic recording. To circumvent the problems of direct acoustic recording, we have decided to record the electrical signal that drives the headphone. This has necessitated minor modifications to the headphone cable and development of some additional electronics so that the electrical signal can be properly digitized. Modification to the headphones as well as construction of the additional electronics were done by TNO-FEL and are described in [2].

A PC-compatible computer with a 16 bit analog-to-digital converter (ADC) board (National Instruments PCI-4451 16-bit ADC/DAC) is used as the data acquisition hardware. Suitable data acquisition software has been developed by DRES using LabVIEW® (a graphical software development tool)[1]. The hardware/software combination provides a very user-friendly way of collecting and storing on disk digitized audio output of a detector as a function of position of its search head.

3.4 General Procedure

One basic process inherent in almost all of the In-Air Tests is the determination of the maximum distance that a target can be detected from the sensor head. In manually conducted tests, an operator listens to the audio output of the detector while passing a target by hand under the detector at a progressively increasing distance, until the operator judges the target to be "not detected". This process, although subjective and results may vary somewhat between operators, is very quick and gives practical and

[1]National Instruments Corporate Headquarters, 6504 Bridge Point Parkway, Austin, TX 78730-5039

useful data. However this process cannot be easily recreated with machines, mainly because the human real-time decision making and feedback is not used and some sort of computer processing (to remove the bias of an operator) needs to be employed (likely offline) to determine the maximum detection distance. Hence there is a need to store detector output corresponding to a target placed at a number of distances from the detector. To this end, targets are positioned on a specially designed device to precisely move a target up and down (Fig. 5) to control target distance. To keep the data volume at a reasonable level detector output data will be collected only at five discrete target distances which bracket an operator-determined maximum detection distance, d_{op}. The operator can detect the target at d_{op}, but not for distances greater than d_{op}. The operator will first determine d_{op} by listening to detector output as a second operator adjusts the target distance based on the feedback from the former. The five discrete distances chosen are $d_{op} - 4$ cm, $d_{op} - 2$ cm, d_{op}, $d_{op} + 2$ cm and $d_{op} + 4$ cm.

Note: *The above procedure was followed at the start of the In-Air Tests and our intent was to use it for all the tests. However, at the IPPTC project meeting at DRES held during 19-20 October 1999, it was agreed that to follow such a process for all the planned tests would be very time consuming and would yield an enormous volume of data. As well, a suitable automatic data processing technique had not been identified and the only proposed post processing technique was playing the collected data back to human operators. Ways to reduce time required for the tests were discussed and it was agreed that some of the tests could be done without storing data for post processing but relying instead on the operator-determined maximum detection distance. For tests where the relative effect of a parameter on the performance of a given detector were to be determined, it was agreed that undue bias would not be introduced by having an operator make the determination of maximum detection distance. An example of such a test would be the Moisture Test where our intent is to determine the* **change** *in sensitivity of a detector as a function of the amount of water sprayed on the search head. The absolute value of the maximum detection distance is not as important in this case as the relative change in this distance caused by moisture. Thus, as long as the same operator is used for the entire Moisture Test for a detector, operator bias should not unacceptably affect the information being sought from this test. Other tests where we relied only on operator decision were Calibration and Drift. Detector output was recorded for the Sweep Speed, Sensitivity and Scan Profile Tests.*

Further details of setup procedures and individual tests are given in Section 4.

3.5 Targets

A total of 11 target types will be used for these trials. Of these, seven are inert landmines and landmine-like objects and the remaining four are metal test objects. The landmine targets are supplied by the US with technical support from TNO-FEL, MTM (a private Dutch company[2]) and C. King Associates in the UK. It is assumed that the

[2] Munitie Technologische Modellen, Rijshornstraat 73, 1435 HG Rijsenhout, The Netherlands

inert landmines and landmine-like objects were prepared in such a way that the dimensions, the type of metal, the relative positions and orientations of all metal components were the same as in the corresponding landmine in the armed state. So, for all practical purposes these targets should behave the same way as the corresponding real landmines as far as metal detectors are concerned. Description of the real landmines can be found in many places including [4]. A brief description of the targets, taken from the TNO-FEL report [2], follows. The IPPTC designation for the actual item (out of a number of available copies of each target type) used in our tests is shown in parenthesis beside the name of the landmine or the test piece.

3.5.1 Inert landmines and landmine-like objects

PMN (Z-2-11) Original Russian **PMN** landmines with replica detonators made by Colin King Associates. Fuse mechanism is put in armed position and blocked to prevent activation. Targets are filled with an imitation explosive charge (bitumen-covered sulphur) by MTM.

PMN-2 (Z-3-02) Original Russian **PMN-2** landmines with original aluminium detonators (which have been inerted) and booster spring. Fuse mechanism is put in armed position and blocked to prevent activation. Filled with an imitation explosive charge (silicone rubber RTV3110, Dow Corning) by TNO-FEL.

PMA-2 (Z-4-01) Original Yugoslavian **PMA-2** landmines with original aluminium detonators which have been inerted. Detonator capsule is in armed position. Filled with an imitation explosive charge (silicone rubber RTV3110, Dow Corning) by TNO-FEL.

PMA-3 (Z-1-01) Original Yugoslavian **PMA-3** landmines, with replica PVC detonators and fuse assemblies fabricated by C. King Associates. There is no imitation explosive charge filling and are used with the metal spring band in place.

Type 72A (Z-5-01) Original Chinese **Type 72** antipersonnel landmines. Fuse mechanism is in armed and blocked position. Replica aluminium detonators are used. Filled with an imitation explosive charge (silicone rubber RTV3110, Dow Corning) by TNO-FEL. **In the various IPPTC reports, this target may be interchangeably referred to as Type 72A or simply Type 72**

R2M2 (Z-6-01) Surrogate landmines fabricated by C. King Associates. Consist of complete replica fuse assemblies in waterproof housings of the correct height. Filled with

an imitation explosive charge (silicone rubber RTV3110, Dow Corning) and foam by TNO-FEL.

PMD-6 (Z-0-11) Exact replicas of **PMD-6** landmines fabricated by MTM, complete with original RO-1 detonator. Fuse mechanism is put in armed position and blocked to prevent activation. Filled with an imitation explosive charge (silicone rubber RTV3110, Dow Corning) by TNO-FEL.

3.5.2 Metal test pieces

$\mathbf{G_0}$ (Z-7-01) A target simulant [5], $\mathbf{G_0}$ is a very small copper tube, 12.7 mm (0.5 inch) long, 3.175 mm (0.125 inch) in diameter and with a wall thickness of 0.381 mm (0.015 inch). Its mass is 0.393 g. Each $\mathbf{G_0}$ test object is placed in a landmine simulant shell with a diameter of 57 mm.

$\mathbf{I_0}$ (Z-8-01) A target simulant [5], $\mathbf{I_0}$ is a small aluminium tube, 12.7 mm (0.5 inch) long, 4.75 mm (0.187 inch) in diameter and with a wall thickness of 0.381 mm (0.015 inch). Its mass is 0.172 g. Each $\mathbf{I_0}$ test object is placed in a landmine simulant shell with a diameter of 88 mm.

$\mathbf{M_0}$ (Z-10-01) A target simulant [5], $\mathbf{M_0}$ is a large aluminium tube, 38.1 mm (1.5 inch) long, 6.35 mm (0.25 inch) in diameter and with a wall thickness of 0.381 mm (0.015 inch). Its mass is 0.66 g. Each $\mathbf{M_0}$ test object is glued to a PVC holder (dimensions:42X42X8 mm). **This target is used in all the In-Air Tests and is often referred to simply as the Al Tube in the test logbooks and elsewhere.**

STP (STP) This is the test pin that comes with the Schiebel AN19/2 mine detector. This target is included in the In-Air Tests so that one could compare certain results from these tests with those of tests conducted previously by DRES and others.

3.6 Detectors

The detectors tested are listed below. The left column shows the designation assigned by IPPTC to each detector while the right column includes the manufacturer's model number. The three samples of each detector model will be referred to by the IPPTC

designantion followed by a -1,-2 or -3 respectively. Thus the three Minelab F1A4-CMAC detectors will be referred to as **MICM-1, MICM-2, MICM-3**. The reader should consult manufacturers' instruction booklets for technical information on these detectors.

AD25	Adams Electronics AD2500
AD26	Adams Electronics AD2600
EB53	Ebinger EBEX 535
EB42	Ebinger EBEX 420 GC
FI12	Fisher Research 1235X
FIIM	Fisher Research Impulse 10.5"
FIXB	Fisher Research 1266 XB 8"
FOMI	FOERSTER Minex 2FD 4.400.01
GIAT	GIAT Model F1 (DHPM-1A)
GUA2a	Guartel MD2000 (round search head)
GUA2b	Guartel MD2000 (long probe)
GUA2c	Guartel MD2000 (short probe)
GUA4	Guartel MD4
GUA8a	Guartel MD8 (round search head)
GUA8b	Guartel MD8 (oval search head)
GUA8c	Guartel MD8 (probe)
LGPR	LG Precision PRS 17K
MICM	Minelab F1A4-CMAC
MIMI	Minelab F1A4-MIM
PRMA	Pro Scan Mark 2 VLF
REMI	Reutech Midas PIMD
SCAN	Schiebel AN-19/2
SCAT	Schiebel ATMID
SCMI	Schiebel MIMID

VA16	Vallon ML1620C
VAVMa	Vallon VMH2
WHAF	White's AF-108
WHSP	White's Spectrum XLT
WH59	White's DI-PRO 5900

4. Details of Tests

This section provides a description of set-up procedures common to most of the tests as well as a description of the tests themselves. *These are very detailed technical instructions, written as "checklists", mainly for personnel who will conduct the In-Air Tests. A familiarity with the mechanical scanner as well as with the data acquisition system is assumed.* Examples of pages from the logbook, referred to in this section, are included as Annex B.

4.1 Setup Procedures

This subsection presents instructions for mounting a detector on the scanner. An outline of the set-up procedures to be followed prior to conducting the individual tests is also given.

4.1.1 Mounting the Detector on the Scanner

1. Test the detector batteries using a Micronta Model 22-096A Battery Checker to ensure that they rate "good". Replace any batteries that indicate "questionable" or "replace".

2. Fasten the detector staff on the scanner carriage using the two clamps and four plastic bolts provided or other nonmetallic fasteners as required. The portion of the staff extending below the lower clamp should be as short as possible in order to reduce flexing during the tests. Wrap sensor cables around the staff, if required, after clamping to prevent cable damage. Try to minimize the weight above the clamps. If the control box can be separated from the rest of the detector, it may be suspended from the structure above the barrel cam. The top portion of the scanning box and the counter weight on the rod may be used to help support and secure the weight of the detector and thus reduce flexing. The cable routing should ensure that it does not catch or snag on any part of the structure and cause undue stress to the cable.

3. Ensure that the sensor head is parallel to the target platform and to the scan plane which is horizontal. This can be achieved by using the staff and sensor-head joint to rotate the head about an axis parallel to the barrel

cam, and by rotating the staff about an axis perpendicular to the barrel cam. Tighten the four clamp bolts evenly to maintain the alignment. Tighten the clamps just enough to prevent the shaft from slipping in the clamps as there is a danger of the bolts breaking or the staff deforming. Ensure also that the bolt in the staff and sensor head joint is properly tightened (do not over tighten) so that the sensor head does not droop.

4. For each detector model, a set of headphones and cable were modified by inserting a pair of mating 5 pin XLR connectors in the cable. Connect the detector female XLR to the extension cable. The extension cable is connected to a junction box. Connect the male XLR from the headphone to the remaining XLR connector on the junction box. This reconfiguration allows digital recording of the electrical signal driving the headphone as well as listening to the audio output from the detector at the same time.

4.1.2 Aligning the Target and Detector

We now describe some basic mechanical procedures to establish a suitable area that can be conveniently scanned when using 2-D scanning. The extent and the exact location of this area will depend on the geometry of the search head and staff of a particular detector. The procedure also ensures that the target holder is located near the centre of this area. For convenience, let us define an origin at the far left corner of the scanner frame (as viewed by an observer standing beside the motor and facing the scanner) and designate a line parallel to the barrel cam as the x-axis and a line perpendicular to this as the y-axis (Fig. 4). Then the area of the scanner frame is defined by: $0 \text{ cm} \leq x \leq 100 \text{ cm}$ and $0 \text{ cm} \leq y \leq 100 \text{ cm}$, and the co-ordinates of the centre of the frame will be at x = 50 cm and y = 50 cm. Reference distances from the sensor head to the top of the target platform and target will also be determined so that reading the relative positions from rulers fastened to the scanner can be used to calculate actual target and scanner head locations.

1. Position the target holder platform at the middle of the one-meter side to side scan, that is, with its centre on the line x = 50 cm and within ± 10 cm (estimate by eye) of the line (parallel to the x-axis) that bisects the scanned area which will be determined in the next step. We should note that the extent of the useable scanned area along the y-axis is about 0.75 m in length depending upon sensor head size and mounting arrangement.

2. Remove the target, if one is present, from the target platform. Lower the target platform so that it will not touch the sensor head when the latter is moving. Determine the range of movement available in the y-axis direction by first moving the detector head close to the start position (near to the origin at the top left corner of the frame). Keep the sensor head 3 to 5 cm from the corner post (used to support the square frame) to prevent

damage. Using the tape measure affixed to the left side of the scanner frame, measure the y-axis position (choose an integral cm mark) of the far vertical edge (the edge close to the origin) of the gearbox. Record this measurement as "carriage position" in the logbook for the Scan Profile Test. Move the sensor along the y-axis until the clutch disengages when the gearbox reaches its limit of motion at the lower left corner of the frame. Note the y-axis position of the same vertical edge of the gearbox corresponding to this new position of the carriage. These two positions determine the extent of travel in the y-axis direction. Calculate the middle point between these two values and move the sensor along the y-axis so that it is over the middle of the target platform. If the target holder position was correctly estimated in the previous step, the y-axis reading of the carriage position should be within ± 10 cm of the line bisecting the scanned area. If not, a repositioning of the target platform along the y-axis direction should be done.

Note: *For the five tests where the sensor head repeatedly moves over a target along a single line, record the final y-axis reading as "carriage position" in the logbook. In addition, for these tests, the carriage should be locked in place by inserting a rubber wedge to each side of the gear that moves the carriage along the y-axis and the gear box must not be engaged.*

3. Move the barrel cam carriage to the middle of the cam by positioning the groove-following shoe at the well defined intersection of grooves at the centre of the barrel cam. Raise the target platform to within 2 cm of the sensor head. Adjust the position of the target platform so that its centre lies directly under the centre of the sensor head. Raise the target platform such that it just touches the bottom of the sensor head. Use the tape measure affixed to the vertical staff of the target holder to record the position of a reference point on the arm of the target holder. This reading is called Ref 1 in the logbook.

4. Place and centre a target (in a predetermined orientation) on the target platform, making sure that it is directly under the centre of the sensor head. Move the target platform so that the highest point of the target just touches the bottom of the sensor head. As in the previous step, note the position of the reference point on the vertical tape measure. This reading is called Ref 0 in the logbooks. Ref 0 will be used in the calculation of target distance from the sensor head. Ref 1 is recorded as a check of procedures (Ref 0 should equal Ref 1 added to the target's vertical dimension).

5. Move the detector to the left end of the barrel cam. To ensure a repeatable x = 0 cm start position for all scans, align the inscribed black mark on the detector carrier to a similar mark on the barrel cam. In the case of 2-D scanning (required for the Scan Profile Test), position the scanner in the

upper left start position, align the two marks as already described and then put the transmission in gear in the middle position (one marked 2 cm/M).

6. Ensure that the clutch is engaged prior to starting a data collection run.

   Note:*Disengaging the clutch eases the moving of the detector along the barrel cam during positioning.*

4.1.3 Setting up the Data Acquisition Program

The following are the steps in setting up the data collection program.

1. Turn the computer on, enter ipptc for the user name, then enter the password.

2. Open Measurement and Automation on the desktop. Following are selections to be made:

   - select Devices and Interfaces
   - select National Instruments PCI-4451 16-bit ADC/DAC
   - select device number
   - select test resources
   - select OK passed test, or in case of error request service to rectify the problem
   - select run test panel
   - select start: a graph should appear and fatal error should not light, in case of error request service to rectify problem
   - select exit criteria: close and OK
   - select National Instruments DAQCard–AI–16XE–50
   - select device number
   - select test resources
   - select OK passed test, or in case of error request service to rectify the problem
   - Select run test panel
   - select start: a graph should appear and fatal error should not light, in case of error request service to rectify problem
   - select exit criteria: close and OK
   - close Measurement and Automation

3. Select the program "ipptc scan_emi" from desktop.

4. Viewing the front panel displayed in the Labview® program started in step 3 above, ensure that:

- the duration is appropriate for the test
- sample rate is 40000
- samples/iteration is 2000
- time window to average is 100.00 msec
- encoder pulse/mm is 1.50
- positional resolution is 10.00
- decimate graphs is 4
- the middle graph (power vs. time) is disabled
- a valid location is in the default directory box starting out with drive e: or f: followed by \ipptc\data\detector_designation.
- using LabView® schematic diagram ensure that the ADC input ranges for channels 0 and 1 are appropriate (i.e. generally ± 5 Volts and AC coupled; if a detector output provides only two DC voltages, select DC coupled)

5. Ensure that the motor controller is set to the correct speed, the direction switch is on Brake and Power is on. Also ensure that the barrel cam is zeroed and properly positioned and the detector is operating properly.

6. Run the LabView® Virtual Instrument (VI) using the left (one time) run arrow in upper left corner of the window. Click on the Freeze Filename button, watch the time remaining indicator and once it starts to count down turn the direction switch on the motor controller from Brake to Reverse. After the remaining time has reached zero, turn the motor controller to Brake. Record the Filename immediately in the logbook.

4.1.4 Setting up the Amplifier Gain

The following are steps to ensure that the detector output signal is at a proper level for the data collection electronics. These steps should be followed before collecting any data with a given detector.

1. Ensure that the detector is set up according to manufacturer's instructions and it is working properly.

2. Ensure that the data collection program and the computer are working properly.

3. Set the default directory to a temporary folder.

4. Enter duration of 600 seconds.

5. Run the data acquisition program.

6. With the sensor head stationary, pass a large metal object (e.g., a wrench) over it while the operator watches the top graph on the display. Adjust the gain switch on the amplifier to provide a maximum peak signal of about ±3 volts. The default input range of the ADC is ±5 volts, which should not be exceeded. The input range could be reduced to ±1 volt by making appropriate changes to the program, but it is not recommended unless the amplifier gain selection cannot provide maximum peak input signal in the ±1 volt to ±4 volts range. At any rate, ensure that the dynamic range is such that the signals near the threshold of detection are adequately recorded and relax the concern for fidelity of very large signals. If there is any doubt, record some data and use the playback feature to confirm the settings.

4.2 The Tests

Now we will describe in detail the steps of the series of tests introduced in section 2.

4.2.1 The Calibration Test

This test determines the repeatability of the initial setup or "calibration" procedure of a detector.

1. Mount the detector in accordance with procedures described in Section 4.1.1.

2. Ensure that the amplifier gains and detector volume/loudness controls have been set correctly, using procedures in Section 4.1.4.

3. Record names of operators, start date, room temperature, detector model, amplifier gain, ADC input range and coupling mode, and detector settings in the logbook.

4. Set the motor controller Speed at 40%, Brake on and Power on. Ensure the clutch is engaged on the scanner.

5. Use the target $\mathbf{M_0}$ in vertical orientation for this test. Prepare the scanner and target alignment in accordance with procedures in Section 4.1.2. Have the detector at the left end of the barrel cam and away from the target. Lower the target platform to avoid the sensor head making contact with the target. Ensure that carriage position, Ref 0 and Ref 1 are recorded in the logbook.

6. Turn on the detector. After letting the detector warm up for at least three minutes, adjust and calibrate the detector in accordance with the manufacturer's instructions. Record the settings and what calibration steps (if any) were taken and when (i.e. prior to each calibration).

Note: *If the batteries require replacing during the test, the warm-up and calibration will need to be repeated.*

7. Without delay, start the scanner motor and raise or lower the target as required to find the position where it is just detectable. Use the vertical tape reading for this position of the target arm and Ref 0 to calculate the maximum detection distance for the target. Place the motor controller to Brake. Record the vertical tape reading and the corresponding maximum detection distance in appropriate places in the logbook.

8. Without turning off the detector, adjust and calibrate the detector again in accordance with the manufacturer's instructions as in Step 6 above. Find the maximum detection distance by repeating Step 7. Repeat this calibration and measurement sequence five times.

9. Proceed to other tests. If this is the last to be done on a detector, reverse the mounting procedure, remove the batteries from the detector and store the detector.

4.2.2 The Drift Test

This test determines how the sensitivity of a detector changes over a half-hour period following an initial warm-up.

1. The detector must have been turned off for at least three hours prior to this test. Previous experience with the detector will be required to determine a suitable target distance and headphone volume settings (if available).

2. Mount the detector in accordance with procedures described in Section 4.1.1. Do not switch on the detector until Step 7.

3. Ensure that the amplifier gains and detector volume/loudness controls have been set correctly, using procedures in Section 4.1.4.

4. Record names of operators, start date, room temperature, detector model, amplifier gain, ADC input range and coupling mode, and detector settings in the logbook.

5. Set the motor controller Speed at 40%, Brake on and Power on. Ensure the clutch is engaged on the scanner.

6. Use the target $\mathbf{M_0}$ in vertical orientation for this test. Prepare the scanner and target alignment in accordance with procedures in Section 4.1.2. Have the detector at the left end of the barrel cam and away from the target. Lower the target platform to avoid the sensor head making contact with the target. Ensure that carriage position, Ref 0 and Ref 1 are recorded in the logbook.

7. Turn on the detector and start a stopwatch at the same time.

8. After three minutes, adjust and calibrate the detector in accordance with the manufacturer's instructions.

   Note: *do not make any further adjustments to the detector until the test is complete. If the batteries require replacing during the test, the entire test will need to be repeated.*

9. Without delay, start the scanner motor and raise or lower the target as required to find the position where it is just detectable. Use the vertical tape reading for this position of the target arm and Ref 0 to calculate the maximum detection distance for the target. Place the motor controller to Brake. Record the vertical tape reading and the corresponding maximum detection distance in appropriate places in the logbook. Note and record the elapsed time from power on for each measurement.

10. Repeat Step 9 every three minutes for 11 measurements.

11. Proceed to other tests. If this is the last to be done on a detector, reverse the mounting procedure, remove the batteries from the detector and store the detector.

4.2.3 The Sweep Speed Test

This test determines how the sensitivity of a detector changes as a function of the speed with which the detector head is swept over a target.

1. Mount the detector in accordance with procedures described in Section 4.1.1.

2. Ensure that the amplifier gains and detector volume/loudness controls have been set correctly, using procedures in Section 4.1.4.

3. Record names of operators, start date, room temperature, detector model, amplifier gain, ADC input range and coupling mode, and detector settings in the logbook.

4. Use the target $\mathbf{M_0}$ in vertical orientation for this test. Prepare the scanner and target alignment in accordance with procedures in Section 4.1. Have the detector at the left end of the barrel cam and away from the target. Lower the target platform to avoid the sensor head making contact with the target. Ensure that carriage position, Ref 0 and Ref 1 are recorded in the logbook.

5. Set the motor controller at the desired sweep speed (choose from 30, 40, 50, 60, 70, 80, 90, and 100%), Brake on and Power on. Ensure the clutch is engaged.

6. Ensure that the recording duration time is correct for the chosen sweep speed.

7. Ensure that the detector is turned on. After letting the detector warm up for at least three minutes, adjust and calibrate the detector in accordance with the manufacturer's instructions prior to test at each sweep speed. Record the settings and what calibration steps (if any) were taken and when (i.e. prior to each sweep speed test).

   Note: *If the batteries require replacing during the test, the warm up and calibration will need to be repeated.*

8. Without delay, start the scanner motor and raise or lower the target until the maximum detection distance is found as was done in the Calibration and Drift tests. Stop the scanner by switching the motor controller to Brake.

   Note: *Since the detector could be moving quite fast for some of the sweep speeds (≥ 50 %), added caution should be taken during this test. Do not continue and immediately turn the motor controller to Brake if there appears to be: (a) a risk of breaking some part of the detector or scanner; (b) the sensor head changes position or bounces violently; or (c) the detector fails to operate as expected. Never let the target get closer than 1 cm to the sensor head while the scanner is in motion.*

9. Now position the target 4 cm closer to the sensor head than the maximum detection distance found in the previous step to begin data collection at the chosen sweep speed. If the maximum detection distance found was 10 cm, for example, then the start position of the target will be at 6 cm from the sensor head. The data corresponding to the target at five distances (e.g., 6 cm., 8 cm, 10 cm, 12 cm and 14 cm in our example) will be recorded in a single file. Since six passes of the detector over the target will be made for each target distance, the target will remain undisturbed for passes 1-6, 11-16, 21-26, 31-36 and 41-46. The target will be lowered 2 cm only during passes 7-10, 17-20, 27-30, and 37-40 and data corresponding to these passes will be ignored in the post analysis. Ensure that pass 46 was completed prior to the expiry of the set collection time.

   Note: *There will be cases where the maximum detection distance is only 3 or 4 cm. Only use four distances in such cases: start by positioning the target 2 cm (instead of 4 cm) closer to the sensor head and lower the target during passes 17-20, 27-30, and 37-40. If the maximum detection distance is only 1 or 2 cm., use three distances (starting from the maximum detection distance) and lower the target during passes 27-30 and 37-40. If the target is not detected at 1 cm, then collect all data at only 1 cm and do not lower the target.*

10. Start the computer data acquisition program. Call out the scan numbers to ensure that the target is lowered as required in Step 9 above. After the

preset data collection time has elapsed and the data acquisition program has stopped, switch the motor controller to Brake. Record the Filename in the logbook.

11. Repeat Steps 5 to 10 until data at all desired sweep speeds have been gathered.

12. Proceed to other tests. If this is the last to be done on a detector, reverse the mounting procedure, remove the batteries from the detector and store the detector.

4.2.4 The Moisture Test

This test determine the effect on sensitivity of moisture applied to the sensor head.

1. Mount the detector in accordance with procedures described in Section 4.1.1.

2. Ensure that the amplifier gains and detector volume/loudness controls have been set correctly, using procedures in Section 4.1.4.

3. Record names of operators, start date, room temperature, detector model, amplifier gain, ADC input range and coupling mode, and detector settings in the logbook.

4. Set the motor controller Speed at 40%, Brake on and Power on. Ensure the clutch is engaged on the scanner.

5. Use the target $\mathbf{M_0}$ in vertical orientation for this test. Prepare the scanner and target alignment in accordance procedures in Section 4.1.2. Place a sheet of polyethylene over the target and target platform to keep them dry. Ensure that it will cause minimum interference to the target and sensor head. Have the detector at the left end of the barrel cam and away from the target. Lower the target platform to avoid the sensor head making contact with the target and polyethylene sheet. Ensure that carriage position, Ref 0 and Ref 1 are recorded in the logbook.

6. Ensure that the detector is turned on. After letting the detector warm up for at least three minutes, adjust and calibrate the detector in accordance with the manufacturer's instructions. This will only be done once during this test. Record the settings and what calibration steps (if any) were taken and when (i.e. prior to start of the Moisture Test).

   Note: *If the batteries require replacing during the test, the entire test will need to be repeated.*

7. Start the scanner motor and raise or lower the target as required until the maximum detection distance is found, using the procedures described under the three previous tests.

8. Spray the sensor head with a fine water mist on top and bottom. Determine the maximum detection distance again.

9. Repeat Steps 8 and 9 for increasing of levels of wetness of the search head. Control the amount of applied water such that the selected range of wetness (from dry to completely wet) is covered in 5 to 8 steps. Find the maximum detection distance for the target for each of these wetness levels.

10. Dry the detector with towels and leave overnight to further air dry.

11. Proceed to other tests. If this is the last to be done on a detector, reverse the mounting procedure, remove the batteries from the detector and store the detector.

4.2.5 The Sensitivity Test

This test determines a detector's ability to detect a variety of targets by measuring the maximum detection distance of a number of targets.

1. Mount the detector in accordance with procedures described in Section 4.1.1.

2. Ensure that the amplifier gains and detector volume/loudness controls have been set correctly, using procedures in Section 4.1.4.

3. Record names of operators, start date, room temperature, detector model, amplifier gain, ADC input range and coupling mode, and detector settings in the logbook.

4. Set the motor controller Speed at 40%, Brake on and Power on. Ensure the clutch is engaged on the scanner.

5. Ensure that the Data Acquisition Program is configured properly and that the recording duration used is correct for the Sensitivity Test.

6. Select one of the 11 targets used in this test and prepare the scanner and target alignment in accordance with procedures in Section 4.1.2. Have the detector at the left end of the barrel cam and away from the target. Lower the target platform to avoid the sensor head making contact with the target. Ensure that carriage position, Ref 0 and Ref 1 are recorded in the logbook.

7. Ensure that the detector is turned on. After letting the detector warm up for at least three minutes, adjust and calibrate the detector in accordance with the manufacturer's instructions prior to collecting data for each target. Record the settings and what calibration steps (if any) were taken and when (i.e. prior to each target).

   Note: *If the batteries require replacing during the test for a target, the warm up and set-up procedure will need to be repeated before measuring the target again.*

8. Without delay, start the scanner motor and raise or lower the target as required to find the position where it is just detectable. Use the vertical tape reading for this position of the target arm and Ref 0 to calculate the maximum detection distance for the target. Place the motor controller to Brake. Record the vertical tape reading and the corresponding maximum detection distance in appropriate places in the logbook.

9. Now position the target 4 cm closer to the sensor head than the maximum detection distance found in the previous step to begin data collection for the given target. The same procedure as in Step 9 of The Sweep Speed Test will be followed. This step is reproduced here for easy reference: If the maximum detection distance found was 10 cm, for example, then the start position of the target will be at 6 cm from the sensor head. The data corresponding to the target at five distances (e.g., 6 cm., 8 cm, 10 cm, 12 cm and 14 cm in our example) will be recorded in a single file. Since six passes of the detector over the target will be made for each target distance, the target will remain undisturbed for passes 1-6, 11-16, 21-26, 31-36 and 41-46. The target will be lowered 2 cm only during passes 7-10, 17-20, 27-30, and 37-40 and data corresponding to these passes will be ignored in the post analysis. Ensure that pass 46 was completed prior to the expiry of the set collection time.

   Note: *There will be cases where the maximum detection distance is only 3 or 4 cm. Only use four distances in such cases: start by positioning the target 2 cm (instead of 4 cm) closer to the sensor head and lower the target during passes 17-20, 27-30, and 37-40. If the maximum detection distance is only 1 or 2 cm, use three distances (starting from the maximum detection distance) and lower the target during passes 27-30 and 37-40. If the target is not detected at 1 cm, then collect all data at only 1 cm and do not lower the target.*

10. Run the LabView® Virtual Instrument (VI) using the left (one time) run arrow in upper left corner of the window. Click on the Freeze Filename button, watch the time remaining indicator and once it starts to count down turn the direction switch on the motor controller from Brake to Reverse. Call out the scan numbers to ensure that the target is lowered as required in Step 9 above. After the remaining time has reached zero, turn

the motor controller to Brake. Record the Filename immediately in the logbook.

11. Repeat Steps 6 to 10 until data for all targets have been acquired.

12. Proceed to other tests. If this is the last to be done on a detector, reverse the mounting procedure, remove the batteries from the detector and store the detector.

4.2.6 The Scan Profile Test

This test determines the scan profile or "footprint" of a detector, that is, the variation of sensitivity as a function of a target's location, with respect to the detector head, in a plane parallel to the search head.

1. Mount the detector in accordance with procedures described in Section 4.1.1.

2. Ensure that the amplifier gains and detector volume/loudness controls have been set correctly, using procedures in Section 4.1.4.

3. Record names of operators, start date, room temperature, detector model, amplifier gain, ADC input range and coupling mode, and detector settings in the logbook.

4. Set the motor controller Speed at 40%, Brake on and Power on. Ensure the clutch is engaged on the scanner.

5. Use the target $\mathbf{M_0}$ in vertical orientation for this test. Prepare the scanner and target alignment in accordance with procedures in Section 4.1.2. Have the detector at the left end of the barrel cam and away from the target. Lower the target platform to avoid the sensor head making contact with the target. Ensure that carriage position, Ref 0 and Ref 1 are recorded in the logbook.

6. Ensure that the Data Acquisition Program is configured properly and that the recording duration used is correct for this test.

7. Ensure that the detector is turned on. After letting the detector warm up for at least three minutes, adjust and calibrate the detector in accordance with the manufacturer's instructions prior to data collection. Record the settings and what calibration steps (if any) were taken and when.

   Note: *If the batteries require replacing during the test then warm up and calibration procedures will need to be repeated.*

8. Start the scanner motor and raise or lower the target until the maximum detection distance is found. Stop the scanner by switching the motor controller to Brake.

9. Collect four data files corresponding to the following four locations of the target, using the 2-D scan mode described before. (a) target 2 cm closer to the sensor head than the maximum detection distance found in previous Step; (b) target 2 cm from the sensor head; (c) target half-way between positions (a) and (b); and (d) no target. The last target condition (no target) provides useful background data. Position the scanner to the far left corner at the start position for 2-D scanning as determined in the set-up process. Initialize the barrel cam as described in Section 4.1.2. Engage the gearbox at 2 cm/M.

10. Run the LabView® Virtual Instrument (VI) using the left (one time) run arrow in upper left corner of the window. Click on the Freeze Filename button, watch the time remaining indicator and once it starts to count down turn the direction switch on the motor controller from Brake to Reverse. The detector head will automatically move through a plane over the target, generating signal vs position data that will be used to produce a 2-D signal map in post analysis. After the remaining time has reached zero, turn the motor controller to Brake. Record the Filename immediately in the logbook.

11. Repeat Steps 9 and 10 until all scan profiles have been acquired.

12. Proceed to other tests. If this is the last done on a detector, reverse the mounting procedure, remove the batteries from the detector and store the detector.

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Annex A
Paper from UXO Forum '98

This is reference [3].

Issues in Performance Evaluation of Metal Detectors

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Abstract

Other than a mechanical prodder, a handheld metal detector is often the only available tool to detect minimum-metal landmines at the present time. Until some other technology that does not rely on metal detection becomes as routine and reliable, the situation will not change. In spite of this, the metal detector is often taken for granted and the consideration given to its performance evaluation and selection is not thorough. Matters are made worse by the commercial availability of a bewildering number of models (most of which were not developed for the specific purpose of mine detection) with various claims of performance. On the other hand, the current landmine problem demands that detectors be able to reliably detect extremely small quantities of metal under various soil and other environmental conditions. This makes proper evaluation and selection of a metal detector all the more important.

We discuss a number of issues, with emphasis on the technical ones, that should be considered in comparing performance of various detectors. These include factors such as the effects of moisture, mineralised soil, electronic drift, operator training, among others, on detector performance. The discussion is illustrated by two recent examples of detector evaluation and selection conducted by the authors - one for the Cambodian Mine Action Centre (CMAC) and the other for United Nations Mine Action Centre (UNMAC) in Bosnia-Herzegovina.

Although the paper will deal mainly with the performance evaluation and selection of handheld metal detectors in the context of landmine detection, much of the discussion will also be relevant to the role of these systems in UXO detection. As well, some of the points raised may benefit the design, conduct, and understanding the results of tests aimed at comparative evaluation of other detector systems such as various forms of vehicle-mounted sensors.

1

1 Introduction

An excellent account of the development and role of the metal detector for landmine detection during World War II is given in [1, 2]. Although decades of research have since been conducted worldwide into a wide range of technologies for the detection of landmines the handheld metal detector, with the possible exception of the mechanical prodder, is still the most frequently employed tool to detect landmines. Until some other technology that does not rely on metal detection becomes as routine and reliable, the situation will not change. In spite of this, the metal detector is often taken for granted and the consideration given to its performance evaluation and selection is not always as thorough as it could be.

Recent development of metal detectors has been primarily driven by commercial interests of the private sector and as a result a large number of models with various claims of performance have become commercially available. However, to the best of our knowledge, most of these were not developed to meet any specific Statement of Requirement (SOR) for mine detection. On the other hand, the current landmine problem demands that detectors be able to reliably detect extremely small quantities of metal (e.g., that found in a M14 or 72A antipersonnel landmine buried upto 10 cm) under various soil (e.g., magnetic soil) and other environmental (e.g., wet tropical) conditions. To do this reliably and effectively is extremely difficult even for the most sophisticated of the modern detectors. This makes proper evaluation and selection of a metal detector all the more important at the present time. We do not pretend to provide the "answers" to this difficult issue, but we would only like to present what we consider to be some of the important factors that must be considered when assessing the performance of a metal detector used to detect landmines. Our views are based on our own research in metal detection technology and on our experience in testing a large number of detectors from various manufacturers worldwide. We will consider our efforts successful if our views initiate a new look and discussion on the subject of metal detectors among the various stake holders, namely, the user, the manufacturers and the scientific community.

2 Performance Factors

Many countries, including Canada, and most humanitarian demining agencies do not have a Statement of Requirements (SOR) for a mine detector, that is, there is no detailed specification that a mine detector must meet. In the absence of such an end-user document, the task of an agency tasked to conduct tests and select a detector from the many available becomes very difficult. At times detectors are chosen on the basis of ad hoc and poorly controlled "field tests". The following is not meant as a substitute for a SOR; but having been faced with the task of evaluating detectors for organisations without specific SOR's we have come up with a number of factors that we feel should go

into the evaluation of a metal-mine detector. Some of these factors are well recognized in SOR's where such documents exist and applicable military standards are available [3], [4].

2.1 In-Air Sensitivity

While a detector's ability to detect objects in air does not indicate its ability to detect objects buried in the ground, we found that such measurements are very useful. Such measurements, when done with care in a laboratory, provide baseline data that can be used to compare certain basic performance factors of the electronics of a given detector. The following are some of the issues that must be considered in conducting the measurements, evaluating the results, and comparing results of similar tests conducted by others.

2.1.1 Target

Manufacturers' specifications often indicate the maximum distance at which their detector can detect a specified quantity of metal without mentioning any other characteristics of the piece of metal. Also, most manufacturers provide a "test piece" to check the proper functioning of their detector. Sometimes a "test piece" of one vendor is not detected well by another vender's detector. It is well kown that the distance at which a metal object can be detected by a metal detector depends on the object's size, shape, material, orientation, among other parameters. Thus the selection of a suitable set of objects or targets is very important for the purpose of comparing performances of various detectors and results of tests conducted at different times and by different agencies.

The selection of a set of targets, even for a relatively well-understood sensor like a metal detector, is not simple; this is in part because various interested parties hold diverse opinions as to what the results of a test and evaluation procedure is supposed to establish. Some would like the results of a test to indicate with absolute certainty how well a given detector will perform against all landmines. Others will argue that a certain chosen target does not represent any landmine. Although it is possible to classify the hundreds of different types of existing mines into a few generic categories [5] such as antipersonnel (AP) blast, AP fragmentation, antitank (AT) blast, and so on, it will be very difficult to obtain agreement on a small selection of landmines to represent the entire population of existing mines. The situation is made worse by the fact that live mines of the desired types may not be readily available and by the safety issues involved in using live mines. As well, information on exact metal content of various mines is not readily available making the task of reproducing the metal components in a mock-up mine difficult. In all the data bases known to the authors, information on metal content of mines is very qualitative - it is usually stated as "x grms of metal", "contains a striker and a detonator (small/large)", "contains substantial amount of metal", "can be

(very/extremely) difficult to detect", and so on. In some cases detailed drawings of the mines are available, but the exact type of metal is rarely specified. The metal type, if specified at all, is usually stated as steel, aluminum, etc. - no detail of chemical composition or electrical properties are given. Such information, if desired, can only be obtained by detailed chemical analysis of a real sample or from the manufacturer if they are willing to provide this information. Then there is the question of variation from batch to batch and model to model of the same mine.

Because of the difficulties just described and due to the limited time and resources available, we narrowed the scope of our target selection. Unless a company claimed and demonstrated that their detector is optimized to detect certain arrangements of metal pieces (as may be found in some mines), we felt it unnecessary to spend the resources to try and recreate these. We reasoned that for a simple baseline comparison of metal detectors, a **variety** of **small** metal targets not unlike parts (e.g., detonators, strikers) found in some minimum metal mines should be adequate. For our purpose, it really did not matter if these pieces represented any real mine at all. With this reasoning we selected, admittedly in a somewhat ad hoc manner, 8 small pieces of metal described in Fig. 1 as our basic target set and complemented it with the Schiebel Test Pin (STP) [1] because of its prevalence in earlier tests. The target set is not claimed to be any kind of "standard" and there is a lot of room for improvement in the exact pieces selected (e.g., a spring like piece is conspicuously missing). However, in situations (e.g., Cambodia and Bosnia-Herzegovina) where it was necessary to know if a particular type of mine could be detected by a certain detector, we used the real fuses in question in addition to our targets.

When we started our work there was no general discussion of standard test targets (one notable exception is [6]), and countries and agencies used targets suitable for their immediate purpose. Currently, however, there are at least six international organizations [2] that are considering mine detector test and evaluation procedures including selection of targets.

2.1.2 Drift

One basic performance factor of any electronic instrument should be its stability. In the context of metal detectors, this factor will determine the degree to which a detector's sensitivity will vary with time. A reduction in sensitivity with time without warning to the operator could be potentially dangerous. One needs to know if a detector maintains

[1] A small test piece, resembling a striker, that comes with Schiebel AN19/2 detectors.

[2] These are: International Test and Operating Procedures(ITOPS), UK/US/GE/FR; Anglo-French Defence Research Group (AFDRG), FR/UK; NATO SGE AC/243 (CET) and RSG1 US/FR/GE/NL/IT/DK/UK/CA; European Commision Joint Research Centre (JRC), EU member countries; The Technical Co-operation Program (TTCP), AU/CA/NZ/UK/US; and Information Exchange Annex (IEA) 1506, US/UK.

its sensitivity without operator readjustment over a desired period of time. We were informed by users that a detector must maintain its sensitivity within acceptable limits over a half-hour period in order to avoid the need for frequent adjustment and to gain operator confidence.

In our tests, after an initial warm-up period, we adjusted a detector according to its manufacturer's recommended procedure and measured the maximum depth at which it could detect a selected target. We then repeated this measurement, without readjusting the detector, every 2 minutes over a period of 30 minutes. This procedure revealed significant variation in sensitivity drift among the various models, including one case where the detector was considered totally useless in spite of its excellent initial performance.

2.1.3 Moisture

In 1995, we received reports from the field that the Canadian Forces' in-service mine detector suffered partial or total loss in sensitivity under certain moisture conditions. After months of investigation and following some blind alleys, we discovered the mechanism that causes the effect. The details of our study which is described in [7] is beyond the scope of this paper. Suffice it to say that if any moisture gathered on the search head, even as little as what can be expected when working over dew-covered vegetation, the detector suffered significant loss of sensitivity - the magnitude of the loss depending on the amount of moisture on the head - without warning the operator. We later established that if the operator were aware of the moisture condition he/she could readjust the detector to restore sensitivity until moisture conditions changed again. We also found that not all detectors were susceptable to moisture to the same degree, if at all.

The above experience prompted us to include a "moisture test" in our repertoire of basic tests on metal detectors. The test consists in measuring the detection distance of a target (usually one or two targets are used) as increasing but known amounts of water are sprayed on the search head from a plant spray bottle. Change in detection depth expected from drift alone has to be acounted for in interpreting results of such a moisture test.

2.1.4 Operator

The operator has a significant effect on the distance a target is detected by a given detector. An operator can influence the performance of a detector in a number of ways.

In some detectors, an operator sets the initial detection threshold by adjusting a knob attached to a potentiometer while listening to the detector's audio output. Where this threshold is set could vary wildly among operators and even among a sequence of settings by the same operator. The situation is worse in the case of detectors where a very small

shift of the knob produces a large change in detection threshold. Fortunately, in an increasing number of the detectors, the operator is no longer required to make this adjustment.

An operator listens for a change in the audio output of a detector to decide if a target is present. Such a decision will depend critically on an individual operator's aural faculty, judgement, attentiveness, experience and so on, particularly in the case of a small change.

2.1.5 Sweep Speed

The speed at which a detector head is swept over a target has an effect on the distance at which the target can be detected. Sensitivity dependence on sweep speed will vary from detector to detector.

2.1.6 Ambient Noise

Obviously, the presence of ambient radio frequency interference (RFI) and other electrical noise will affect the performance of a detector. Different detectors will be affected differently by such noise.

2.1.7 Construction

Sometimes how a detector is constructed, i.e., the relative placement of various parts and their interaction, could significantly affect its sensitivity. For example, in the case of one detector, the detection depth varied by as much as 30% depending on the tilt of the search head with respect to the shaft. This was determined to be due to the interaction of connecting cable and the search head. In another, the sensitivity was reduced if the connecting cable lay close to the metal parts on the shaft. Such factors must be recognized and accounted for if one were to compare performance.

2.1.8 Battery

The performance of a detector may degrade without warning as the battery voltage goes lower.

2.1.9 Unit to Unit Variation

There will invariably be variation in performance among various units of the same detector. The extent of this variation will depend on the quality control excercised by a

particular manufacturer. Often, it is not possible to test more than one or two units of a model and one has to assume that the manufacturer will meet or exceed the performance of the sample units tested.

2.2 Effect of Soil

A detector's ability to detect targets buried in soil depends, in addition to all the factors already discussed under **In-Air Sensitivity**, on the properties of the burial medium. Since there are many different types and conditions of soil, it would be very difficult to characterize, simulate or control this parameter. Hence, one must recognize the limitations and difficulties associated with indoor or outdoor laboratory "mine lanes". On the other hand, we must also recognize that although burying targets in-situ and conducting detector trials at various theatres of operation provides valuable practical information, it is very difficult to control such trials given limited resources.

The effect of soil on metal detectors was recognized during World War II and some models were fitted with a means to reduce the "pavé effect", so called for its association with road stones containing particles of magnetic iron oxides [1, 2]. During 1945-47, the effect of different rocks and soils on the performance of the U.S. SCR-625 mine detector was studied. In the intervening time since these studies were done the question of the effect of soils on metal detectors appears to have kept a low profile in the mine detection community. In the UXO detection community the soil is usually considered to be essentially transparent to electromagnetic induction sensors - a justifiable assumption based on the large target sizes involved. In cases where the effect of soil has been considered, the focus appears to have been on electrical conductivity and static magnetic susceptibility of soil. It is now known that the predominant effect of soil on induction metal detectors arises from the frequency (or time) dependence of magnetic susceptibility found in certain soils. Soil magnetism and its effect on electromagnetic induction measurements is a subject on its own [10]-[20] and it should be consulted in determing the composition of mine test lanes. However, there are unresolved issues such as: the effect of disturbing the soil or digging it up and transporting, of moisture and temperature, small-scale (order of cms) spatial variation of soil electromagnetic properties. New research into soil electromagnetism aimed specifically at understanding metal detector performance would be of great value. We should mention in passing that soil characterization for evaluation of a ground probing radar (GPR) will be much more complex than it is for the evaluation of a metal detector. Some manufacturers [20] have taken advantage of the difference in response characteristics of magnetic soil and that of metal targets to significantly reduce the adverse effect of soil on their detectors.

2.3 False Alarms

Current metal detectors cannot discriminate between metal parts in a landmine and pieces of scrap metal that are present in almost any location on earth, particularly in areas of previous conflicts. This results in a large number of "False Alarms", determined mainly by the extent of metallic contamination of a particular location and the smallest target signal being sought, and less by the design of a particular metal detector. However, false alarms caused by anomalous soil conditions have been considered by some detector designers with a view to reducing such alarms. The issue of false alarm definition, classification and characterization is a complex one, but it should be addressed in the design, conduct and evaluation of results of any field trial of detectors. The issue is just begining to be adequately addressed particularly in connection with field evaluation of multisensor vehicle-mounted systems[21, 22]. A discussion of these issues is beyond the scope of this paper.

We should also note that because of the potentially extreme variability of soil and other conditions with time, location and weather, it is very difficult if not impossible, to obtain repeatable results from field trials.

2.4 Other Selection Criteria

In addition to the detection factors discussed above, there are other factors which should go into the selection of a mine detector depending on its intended use. Fortunately, these factors are usually well considered in SORs where they exist, or in the acquisition process. We will only briefly mention them for completeness.

2.4.1 Ergonomics

Mechanical configuration, weight and size, ease of use are important factors affecting operator acceptance. Operators seem to prefer light-weight, integrated single units over the conventional detectors with their two or three subunits. A well-designed operator questionnaire should provide valuable input on the ergonomic design of a detector.

2.4.2 Ruggedness

A detector should be evaluated against any applicable military standards. It should be pointed out that many of the detectors on the market were not designed and manufactured to meet any military standards despite the fact that they are being marketed to the military user. As well, ruggedness standards for humanitarian demining will be different from those for tactical use.

2.4.3 Operational Issues

Some of the important operational factors affecting the choice of a mine detector are:(1) Likelihood of the detector setting off mines with a magnetic influence fuze. This factor may not be as important in humanitarian demining applications. In UXO detection, proximity fuzes and other electrically initiated ordnance are of concern. (2) Ability to resolve small antipersonnel mines that may be planted around a larger antitank mine. (3) Minimum separation distance between two detectors before they start to interfere with each other as well as interference from other emitters such as handheld radios will affect the concept of employment.

2.4.4 Management Issues

Since most companies currently marketing mine detectors are relatively small, one needs to consider the ability of a chosen company to provide adequate after sales technical support. The initial and maintenance cost of a detector are important considerations particularly for humanitarian demining. As well, a detector with a planned and inexpensive upgrade path to future technological improvements is highly desirable.

3 Case Studies

We will now briefly describe our involvement in evaluating and recommending mine detectors for the Cambodian Mine Action Centre (CMAC) and for United Nations Mine Action Centre (UNMAC) in Bosnia-Herzegovina. These efforts, although severely restricted due to limited time and resources available, were extremely valuable in clarifying the issues and helping these agencies make informed decisions about metal detector specifications and procurement. On the other hand, we learned a great deal and gained valuable experience in real-life application of mine detectors.

3.1 Support to CMAC

Canadian Forces personnel attached to CMAC reported, in the summer of 1995, that their primary detector, the Schiebel AN19/2, suffered a serious degradation in sensitivity in some moisture conditions. They also reported that this detector was very ineffective in detecting mines buried in mineralised soil (lateritic) which was estimated to be present in 40% of the minefields in Cambodia. A number of competing vendors, who were aware of the situation, began to apply pressure on CMAC to use their detectors instead. This prompted the Chief Technical Advisor (CTA) at CMAC to request Defence Research Establishment Suffield (DRES) to provide assistance in the following areas:(1) Investigate

the moisture problem of the Schiebel detector to identify its cause and suggest possible remedies. (2) Assist CMAC in choosing a replacement for the AN19/2 by conducting and/or by teaching them how to conduct suitable comparative tests.

The first component of this work, that is , the investigation of the moisture problem of the AN19/2 became a separate investigation on its own, the details of which are described in [7]. We were able to identify and reproduce the mechanism that caused the observed behaviour in the field and suggested some measures to reduce the problems. Briefly, the responsible mechanism was electronic and not mechanical as Schiebel had believed. Proper electrostatic shielding and A.C. coupling were recommended as possible solutions. It was also pointed out that these measures, while they will reduce the adverse effect of moisture, will do nothing for the detector's ineffectiveness in a mineralised soil environment.

As regards the second, we drew up a test plan incorporating many of the performance factors already discussed, provided a set of DRES targets, trained CMAC personnel in test procedures, and conducted tests at DRES and on-site at CMAC to recommend detectors most suitable for use in Cambodia. The following mine detectors were evaluated (the number in () brackets indicates number of units of the type):Schiebel AN19/2 Mod2 (1) and Mod7 (2); Guartel MD-8 (2); Ebinger 420PB (1), 420SI (2); Forster 2000SL (3), 2000P (1); Vallon 1620B (2); Minelab F1A1 (1), F1A2 (1), F1A4 (1), F1A4C (1); and RP-507 (1). Some preliminary tests such as **in-air sensitivity** , **sensitivity drift with time** and **effect of moisture** were conducted at DRES before traveling to Cambodia. These tests were done on all detectors expect those from Minelab and the RP-507, which were not available at DRES. We used the DRES targets and the STP in these tests. On site at CMAC, we repeated these tests on a limited number of the previously tested detectors as a check of procedures and on all the detectors not seen before. The tests at CMAC was conducted over the period 5-17 June 1996 (including travel).

On arrival at CMAC, we learned that three selection criteria were of utmost importance - operation over lateritic soil, minimum performance degradation due to moisture, and the ability to detect a 72A antipersonnel landmine buried at least 10 cm deep in lateritic soil. Because of these requirements and the limited time available, we had to restrict ourselves, in spite of a previously laid out plan, to determining which detectors, if any, could meet these demands. In addition to the basic in-air tests already mentioned we conducted detectability tests in a mound of laterite that had been transported, as well as in "natural" laterite on the periphery of a real minefield. A 72A mine was included as a primary target in all these tests. Based on our findings we concluded:(1) Reported deficiencies of AN19/2 in CMAC operations were confirmed; (2) Two detectors, namely, the Minelab F1A4 and the Forster 2000SL among those tested were found to best meet CMAC requirements; and (3) There was need for improved operator training to take full advantage of mine detectors.

3.2 Support to UNMAC

Events leading to our involvement in the mine detector trials conducted under the auspices of UNMAC were similar to those for the CMAC trial. UNMAC, the organization set up to provide supervision and advice for demining in Bosnia-Herzegovina, was aware of deficiencies associated with some metal detectors in use in that country. As usual, there was pressure on UNMAC from vendors. UNMAC decided to seek outside help in the selection of suitable detector(s). Canada and the UK responded with funded offers of assistance. As a result, trials were conducted over a 3-week period in January 1997 in Bosnia-Herzegovina, by a multinational trials team consisting of 2 technical representatives from Canada, 4 UK MOD personnel, 1 Project Officer from UNMAC, and 15 detector operators from 7 countries. Canada was responsible for conducting the laboratory trials (e.g., in-air sensitivity, drift, moisture effect), while the UK accepted the responsibility to conduct the field trials. The Project Officer from UNMAC was responsible for establishing the overall trial objectives, providing logistic support, liaison with manufacturers, demining agencies and SFOR units, assistance in the final assessment of detectors. The aim of the trials was to jointly come up with a list of detectors suitable for use in the location concerned.

Prior to the in-country trial, manufacturers were requested to submit detectors for evaluation. Two units of each detector were requested. Eleven (11) manufacturers responded and provided a total of 26 detectors representing 17 different types. These were: Guartel MD8; Garrett Hunter and Sea Hunter; Forster Minex 2FD 4.400.01 (2000SL) and Metex 4.125.04; Vallon ML 1620B; Whites AF 108 and Surf Master; Schiebel AN 19/2 (Mod 7 only) and Prototype; Ebinger 420PB, 505DS and 505 PD; Minelab F1A4; Emercom UMP-1; Sentio; Reutech. Despite pre-planned thoughts on scope of the trials, field conditions necessitated substantial changes. The following separate assessments/trials were conducted. Additional details of the work can be found in [23]

1. **Sensitivity in Air:** The maximum detection distance was determined for a number of targets including the DRES targets, a Schiebel Test Pin and live fuses from the mines PMA-2, PMA-3, TMA-1A, TMA-2, TMA-3, TMA-4 and TMA-5. (TMA-1A, TMA-2 and TMA-5 use the same fuse.)

2. **Stability in Air:** The variation in detection distance in air over a 30 minute period using DRES Target No.1 (Fig. 1) was measured. Detection distances were measured at two minute intervals after an intial warm-up of 3 minutes.

3. **Stability with Moisture:** The variation in detection distance in air using DRES Target No.1 (Fig. 1), for varying degrees of moisture level on the detector search head was measured.

4.Field Trials: Field trials were conducted using a variety of sites representing poor to good conditions for detector operations. Because of the difficulty in controlling these trials and their subsequent minor impact on final selections, we will not describe them in any detail here. These trials - one on a 15 mxl m test strip in Sarajevo, one on a 30 mX1 m strip at Mostar airport, and one at Buna Quarry - made use of 15 operators at random, used test pieces and simulated mines (except at Buna Quarry where live fuzes were buried) buried up to a depth of 200mm. These trials, in the end, only provided an ad hoc detection rate for the different detectors. However, the most valuable lesson that these trials provided was the need for more careful control and documentation of field trials in future.

5. Field Trial for Minimum Performance: Because of the low confidence in the results of the field tests already described, one final test was conducted by UNMAC under better control to establish a minimum level of performance acceptable to UNMAC. In this test, live fuzes for mines listed under Test.1 were buried just below the surface of the ground in FFE (free from explosive) cases in minefield patterns encountered in Bosnia-Herzegovina and all detectors were passed over the area with different operators to replicate minefield conditions. The soil condition was considered to be "typical" problem soil in the area. For a detector to pass this test it had to detect all the targets.

6. Operator Questionnaire: Each operator was given a questionnaire with questions requiring subjective answers. The operators could be expected to have good experience after two weeks of using the detectors and to make comments on ease of use, operation and maintenance issues, comfort, etc. Each national group of operators completed a questionnaire collectively for each type of detector. As well, each operator was asked to rank the detectors in order of preference according to their personal opinion based their experience with them over the trial period. Although operator feedback did not have direct impact on the final selection, it was of great informational value and was relayed back to manufacturers as required.

7. Manufacturers Questionnaire: Each manufacturer was requested to fill out a questionnaire on their detector model(s) presented for trial. This questionnaire allowed the manufacturers to present in the fullest detail, data for their respective detectors that assisted the evaluation team in understanding each detector's capability.

3.2.1 Selection Strategy

None of the detectors met UNMAC's requirement of detecting all mines to 200 mm depth and there was no single detector that outperformed the rest. As already mentioned, the evaluation team could not place much confidence on the outcome of the initial field trials. However, the trial team was able to jointly come up with a selection criteria based on the

tests. They set pass and fail criteria for each of the tests and decided on the relative weighting to be placed on each test.

In order to pass **Test.1 In-Air Sensitivity** a detector was required to detect an antitank fuze at 140 mm, and an antipersonnel fuze at 90 mm. To pass **Test.2 Stability in Air**, the variation in detection distance over the 30 minute period could not exceed ± 20 mm. To pass **Test.3 Stability with Moisture**, the variation in detection distance with moisture on the detection head could not exceed ± 20 mm. To pass **Test 5. Field Trial for Minimum Performance**, a detector must have detected all the targets. These tests were considered mandatory, that is, for a detector to be included in the final list of suitable detectors it must have passed all these tests.

The criteria of pass for the other field trials were set, in a rather ad hoc manner, at detection of 50% of the targets. However, these tests were given low weightings and hence did not affect the final recommendation.

3.2.2 Recommendations

No detector met the UNMAC requirement of detection for all mines to 200 mm depth. However, based on the results of the tests, the evaluation team recommended (with cautionary notes) that the following detectors were more acceptable for use in the particular theatre, in a greater variety of conditions, than the others presented for the tests: Forster Minex 2000SL, Guartel MD8, Minelab F1A4, and Vallon 1620B. These findings were in general agreement with our findings in CMAC. Both Guartel and Vallon had submitted different detector configurations than those used in CMAC.

4 Lessons Learned

The trials at CMAC and UNMAC reinforced our belief that the commonplace handheld metal-mine detector must not be taken for granted, and that its specification, evaluation and selection should be given the same importance as any other piece of Engineer equipment.

The current mine problem demands that metal detectors be able to routinely detect an extremely small quantity of metal in various soil and environmental conditions. While technology has evolved to respond to this very demanding task, to get the most out of this technology we must take a fresh look at operator training and doctrine of employment of these detectors. Increased sensitivity and electronic sophistication of the modern detectors calls for more in-depth operator training for effective use of these tools.

We found that operators generally lacked confidence in the capabilities of metal detectors in detecting mines. Manufacturers and developers must work to earn their

confidence.

Finally, feedback must be provided to the manufacturers on the weaknesses and strengths of their detectors so that better products can be expected in the future.

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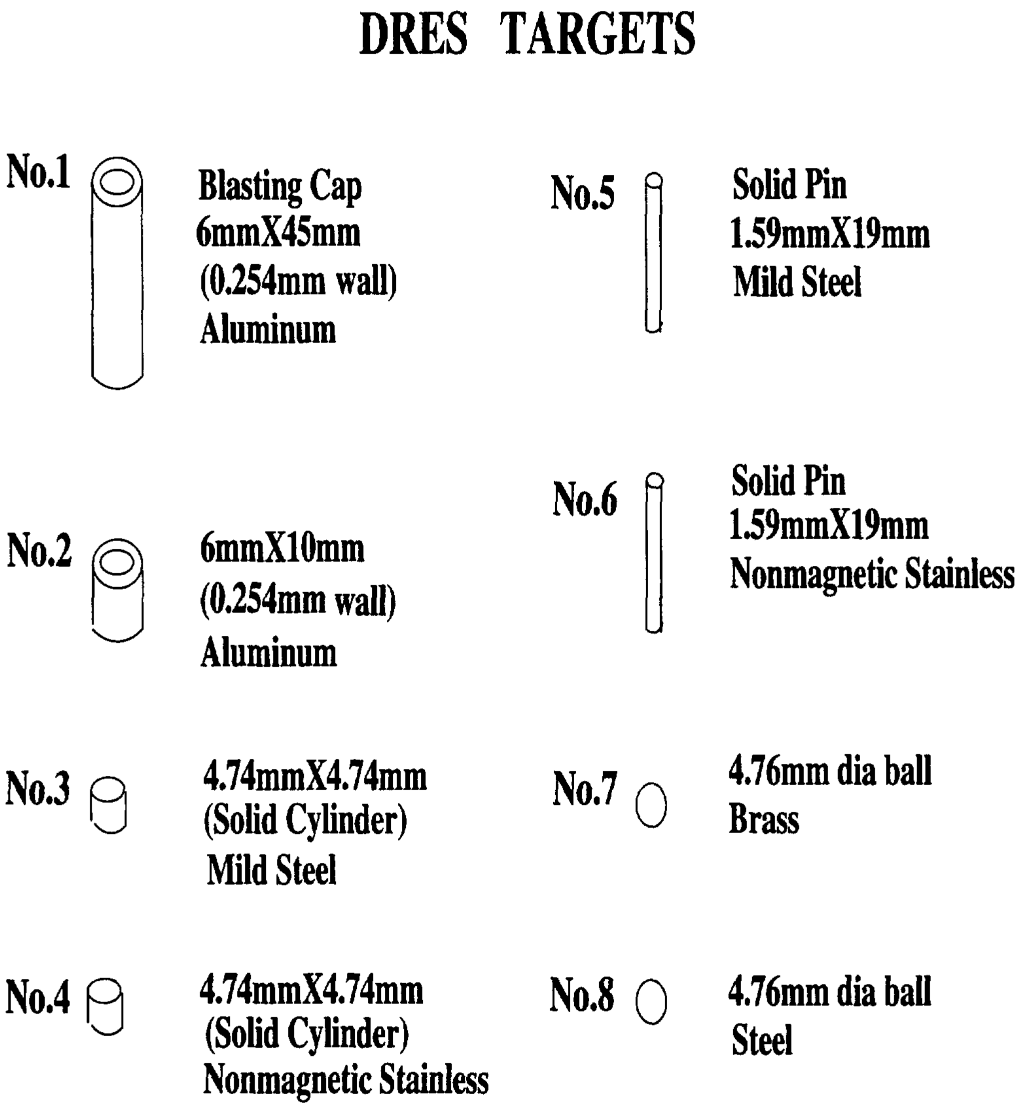

Figure 1: Sample target set.

Annex B
Example Log Sheets

In-Air Calibration Test

Operator 1:	Denis Reidy	IPPTC No.	AD25-1
Operator 2:	Bjorn Dietrich	Date Started (yy-mm-dd)	99-12-02
Operator 3:	Jack Toews	Date Completed (yy-mm-dd)	99-12-02

SETUP INFORMATION

Detector Angle	45				
Line/Area Scan	Line	Gain	X 0.2		
Carriage Position	193.8	Scan Rate	40%	Room Temperature	21
Vertical Ref 1 (Sensor = Platform)	13.1			Detector Turn-on Time	1051
Vertical Ref 0 (Sensor = Target)	16.9			Detector Warm up Time	3 MIN
Maximum Detection Depth				Target Designator	Z-10-01

Detector Settings:

Adjusted 20-turn pot for each run by operator 2 using LED.

FILE LOG

Serial	Maximum Measured Distance	Maximum Target distance	Comments
1	25.9	9	
2	25.9	9	
3	25.9	9	
4	26.9	10	
5	27.9	11	

ADDITIONAL COMMENTS

Battery OK?	Y	Y/N	

DC coupled and filters removed.

In-Air Drift Test

Operator 1: Jack Toews

Operator 2: Bjorn Dietrich

Operator 3:

IPPTC No EB42-2

Date Started (yy-mm-dd) 99-12-13

Date Completed (yy-mm-dd) 99-12-13

942

SETUP INFORMATION

Detector Angle: 45

Line/Area Scan: Line

Gain: X 0.2

Carriage Position: 174.8

Scan Rate: 40%

Room Temperature: 20.5

Vertical Ref 1 (Sensor = Platform): 21.8

Detector Turn-on Time: 908

Vertical Ref 0 (Sensor = Target): 25.5

Detector Warm up Time: 3 MIN

Maximum Detection Depth:

Target Designator: Z-10-01

Detector Settings:

Sensitivity = 4.

FILE LOG

Serial	Maximum Distance Reading	Maximum Target Distance	Comments (elapsed time from power up)
1	49 5	24	6 minutes from power on
2	49 5	24	9 minutes from power on
3	48 5	23	12 minutes from power on
4	49.5	24	15 minutes from power on
5	48.5	23	18 minutes from power on
6	48 5	23	21 minutes from power on
7	48.5	23	24 minutes from power on
8	48.5	23	27 minutes from power on
9	48 5	23	30 minutes from power on
10	49 5	24	33 minutes from power on

ADDITIONAL COMMENTS

Batteries OK Y Y/N

See Calibration for detector parts.

In-Air Sensitivity Test

Operator 1: Bjorn Dietrich

Operator 2: Jack Toews

Operator 3:

IPPTC No. GIAT-3

Date Started (yy-mm-dd) 99-12-07

1250

Date Completed (yy-mm-dd) 99012-07

SETUP INFORMATION

Detector Angle: 45

ADC Input: (+ -) 5 V

Digitizing Rate: 40,000

Line/Area Scan: Line

Gain: X 0.5

Collection Time/File: 200 sec

Carriage Position: 176.3

Scan Rate: 40%

Room Temperature: 21

Vertical Ref 1 (Sensor = Platform): 25.8

Detector Turn-on Time: 1101

Vertical Ref 0 (Sensor = Target): see below

Detector Warm up Time:

Maximum Detection Depth: see below

Target Designator: see below

Detector Settings:

Sensitivity 3; X and R adjusted for null.

FILE LOG

Target Designator	Target	Ref 0	Max Det. Distance	Start Distance	File Name	Comments	Max Target
Z-0-11	PMD-6	31.6	46.6	42.6	991207_135928		15
Z-1-01	PMA-3	29.5	36.5	32.5	991207_133531		7
Z-2-11	PMN	30.9	60.9	56.9	991207_141501		30
Z-3-02	PMN-2	30.8	47.8	43.8	991207_140629		17
Z-4-01	PMA-2	31.6	36.3	32.6	991207_135200		5
Z-5-01	Type 72A	29.4	37.4	33.4	991207_132103		8
Z-6-01	R2M2	31.2	40 2	36.2	991207_125652		9
Z-7-01	Go	28.9	-999	29.9	991207_130442	only 29 9 (1 cm)	no detection
Z-8-01	Io	28.9	33.9	29.9	991207_132822		5
Z-10-01	Al tube	29.3	38 3	34.3	991207_134229		9
STP	STP	32.3	37 3	33.3	991207_131248		5

ADDITIONAL COMMENTS

Batteries OK Y Y/N

Large target gives +10 and -5 volts.

In-Air Sweep Speed Test

Operator 1: Denis Reidy | IPPTC No. REMI-1
Operator 2: Jack Toews | Date Started (yy-mm-dd) 99-11-25
Operator 3: | Date Completed (yy-mm-dd) 99-11-25

SETUP INFORMATION

Detector Angle: 0 (see driftlog for details) | ADC Input: (+ -) 5 v | Digitizing Rate: 40,000
Line/Area Scan: Line | Gain: X 2 | Collection Time/File: see below
Carriage Position: 139 1 | Scan Rate: see below | Room Temperature: 21.5

Vertical Ref 1 (Sensor = Platform): 57.3 | Detector Turn-on Time: 904
Vertical Ref 0 (Sensor = Target): 61 2 | Detector Warm up Time: 3 min
Maximum Detection Depth: | Target Designator: Z-10-01

Detector Settings:

Mode @ LOC; sensitivity @ High;

FILE LOG

Scan Rate	Set Rec. Time to.	Approx. rate/m	Maximum Detect Distance	Start Distance	File Name	Maximum Target Distance
30%	400 sec	7 5 sec	64 2	62.2	* 991125_133806	3
40%	200 sec	4 sec	66.2	62.2	991125_134713	5
50%	150 sec	3 sec	71 2	67 2	991125_135427	10
60%	120 sec	2 sec	71 2	67.2	991125_135933	10
70%	100 sec	1 75 sec	72.2	68.2	991125_140415	11
80%	70 sec	1.38 sec	73.2	69 2	991125_141025	12
90%	60 sec	1.18 sec				
100%	60 sec	1 sec				

ADDITIONAL COMMENTS

Batteries OK y Y/N

* 2@62.2,1@64.2.. ; Did not due runs at 90% and 100% rates due to mass of detector and risk of damage to detector and scanner.

In-Air Moisture Test

Operator 1: Richard Beech

Operator 2: Denis Reidy

Operator 3: Jack Toews

IPPTC No WHAF-1

Date Started (yy-mm-dd) 99-11-02

Date Completed (yy-mm-dd) 99-11-02

SETUP INFORMATION

Detector Angle: 45

Line/Area Scan: Line

Gain: X1

Carriage Position: 176

Scan Rate: 40%

Room Temperature: 22 C

Vertical Ref 1 (Sensor = Platform): -1 4

Detector Turn-on Time: 1242

Vertical Ref 0 (Sensor = Target): 2.3

Detector Warm up Time:

Maximum Detection Depth:

Target Designator: Z-10-01

Detector Settings:

Volume control = 5 o'clock; 'auto tune' before 1st run

FILE LOG

Water Squirts	Maximum Measured Distance	Target Distance	Comments
dry	25.3	23	
1	26 3	24	
2	26.3	24	click rate starting to increase
3	24.3	22	click rate increasing but lights off
4	24 3	22	click rate increasing but lights off
max	24.3	22	click rate = 6 / sec

ADDITIONAL COMMENTS

Batteries OK y Y/N

no lights.

In-Air Scan Profile Test

Operator 1: Jack Toews

IPPTC No SCAT-1

Operator 2. Denis Reidy

Date Started (yy-mm-dd) 99-11-22

Operator 3

Date Completed (yy-mm-dd) 99-11-22
1152

SETUP INFORMATION

Detector Angle 45

ADC Input (+ -) 5 V

Digitizing Rate 40,000

Line/Area Scan (use 2cm/M) Area

Gain X 0.5

Collection Time/File 170 sec

Carriage Position 169

Scan Rate 40%

Room Temperature 21 5

Vertical Ref 1 (Sensor = Platform) 5 9

Detector Turn-on Time 1115

Vertical Ref 0 (Sensor = Target) 10.5

Detector Warm up Time 14 MIN

Maximum Detection Depth

Target Designator Z-10-01

Detector Settings:
Sensitivity @ 730 o'clock; Loudness @ 9 o'clock; startup sequence normal.

FILE LOG

Serial	Measured Distance	File Name	Target Distance	Comments
1	33.5	991122_113425	23	maximum target distance 25
2	23	991122_113905	12.5	
3	12.5	991122_114331	2	
4	no target	991122_115105		

ADDITIONAL COMMENTS

Battery OK? y Y/N
After clutch is disengaged at end, a small amount of noise disappears after motor is turned off

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Das, Y. and Toews, J.D.

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Canada participates in the International Pilot Project for Technology Co-operation (IPPTC) in landmine detection under the auspices of the Canadian Centre for Mine Action Technologies (CCMAT). The goal of this multinational project is to conduct various laboratory and field tests on a number of commercial metal detectors in their use as landmine detectors. Results of these tests will provide relevant information to potential sponsors and end users of such technology to help them make informed equipment choices in humanitarian demining. This report describes the concepts behind and the detail implementation of the laboratory tests, designed and led by Canada, and to be conducted at the Defence Research Establishment Suffield.

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